



MISSOURI DEPARTMENT OF NATURAL RESOURCES

Tree Planting on Missouri's Minelands

Fact Sheet

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Division of Environmental Quality
Land Reclamation Program

Introduction

Missouri mine lands can be very productive forestry sites. Many mine soils can sustain excellent growth for oaks, pecans, hickories and walnuts once soil organic matter is accumulated and the mine soil's nutrient cycling system is established. Good mine soils have excellent potential for forestry practices that with time can greatly increase overall land values and farm income. Good mine soils can be very productive forest lands, exceeding many native soils in growth rates for valuable hardwoods.

Other mine soils can be extremely harsh for tree survival. Some sites are acidic, droughty, rocky, steep and erosive, making tree planting difficult and challenging for the landowner. Planning and good planting techniques are even more essential for good establishment success on these harsh sites.

Successful tree seeding establishment on reclaimed mine lands depends upon seven major factors:

1) selection of proper native species, 2) purchase of the best quality planting stock, 3) correct handling of planting stock, 4) correct planting techniques, 5) effective control of competing vegetation, 6) proper soil conditions and preparation and 7) weather.

Trees are effective in reclamation because they produce large amounts of organic matter in mine soils that promote nutrient cycling. Much of the mine soil's nitrogen and phosphorus are released by the decomposition of organic matter by soil organisms. Tree roots break up compaction by creating root channels. Large tap-rooted species such as bur oak (*Quercus macrocarpa*), swamp white oak (*Quercus bicolor*) and bald cypress (*Taxodium distichum*) are particularly effective in mitigating compaction. Tree root systems stabilize the reclamation site by reducing erosion and sedimentation. Many tree species tolerate high soil acidity and low fertility, typical conditions found on many mine sites. Trees play an important role in good wildlife habitat on many mine sites. Mine lands may be the only large tracts of woodland or timberland in western Missouri.

Selection of Species

Many native tree species are adapted to the often harsh conditions of mine soils and to Missouri's climate. Missouri trees must tolerate drought and extreme heat in summer and saturated soils and freezing conditions in winter. Mine soils are often acidic with low soil fertility, low organic matter content and low water-holding capacity. Compaction by earthmoving equipment results in physical limitations to root growth, soil aeration and water infiltration in graded mine soils. These environmental conditions can pose serious problems in establishing revegetation, particularly trees.



Many native species in Missouri tolerate acidic natural soil conditions. These species may be effective in reclamation since many tolerate acid mine soil conditions as well. Observing natural invasion and succession of native species on acidic mine spoils may provide clues for species selection. (For more information on natural succession and soil formation on mine lands, refer to Technical Bulletin No. 6, ***Tree Species for Missouri Mine Lands***.) Tree planters can purchase many of these species from regional nurseries specializing in native species. (For a discussion of acid mine soils, see Technical Bulletin No. 7, ***Acid-Forming Materials and Acid Mine Drainage on Missouri Mine Lands***.)

Exotic Species

Often, landowners wish to plant nonnative conifers on mine lands. Many species of pine have been successfully established on Missouri mine sites. However, their long-term survival has been limited. Eastern white pine, Austrian pine, pitch pine and jack pine are among many species that have been extensively planted. Typically, Scots pine is short-lived (20-30 years) on mine sites. Very few pines of any species survive past 60 years on mine sites in Missouri. Very few produce seedlings to replace themselves in Missouri. From the 1930s to 1970s, coal companies, conservation groups and private landowners planted a great many pines on mine spoils that are presently declining and dying. Landowners should expect to replace the pines by planting native hardwoods as they die. Otherwise, less desirable species, like elm, may replace the pines, limiting oak or walnut invasion. (For more information on reclamation tree species, refer to Technical Assistance Bulletin No. 6, ***Tree Species for Missouri Mine Lands***.)

Many early plantings on mine lands included exotic plants that have naturalized and become significant problems. Japanese honeysuckle, sericea lespedeza and autumn olive were used to stabilize mine sites but are now spreading into unmined lands at an alarming rate. To avoid future problems, landowners must be careful when planting exotic species. Native plant species tend to have native pests that limit or control their spread. Bristly locust (*Robinia hispida*) is native to the eastern United States and has been planted with great success in the eastern coal fields. It spreads quickly by rhizomes, forming a dense thicket. Many authors suggest that it will not spread into a grass sod, thereby limiting its invasion of unmined lands. However, conditions in Missouri may be such that bristly locust could become a problem. Autumn olive was regarded as noninvasive for many years. Today, it has become a serious problem plant. Without controlled field trials, bristly locust and other species may prove to be a land manager's nightmare, a wonder plant or something in between.

Black locust (*Robinia pseudoacacia*) and **black alder** (*Alnus glutinosa*) were planted extensively on mine lands because they can take nitrogen from the air with the aid of beneficial soil microbes and use it as a plant nutrient. However, these trees spread aggressively and cast a dense shade that does not allow beneficial, native trees like oak to invade the mine site. Black locust often may be the only tree species that can survive extremely acidic soil conditions and its use limited to those sites. Black locust and black alder trees must be removed before oaks and other hardwoods can be established.

Purchasing Planting Stock

Tree survival depends upon good plant materials. Planting poor-quality stock wastes money spent on plant materials, site preparation and planting. The stock should be healthy, showing little damage to roots or shoots and no mold, offensive smell or dry roots. Planting stock is expensive, with prices continuing to rise. Poor-quality stock has little chance for survival and should be returned immediately to the nursery for replacement or credit. Typically, bare-root seedlings with larger calipers (the diameter of the seedling at its root collar) have much greater establishment success than smaller ones. Experienced planters recommend that most conifers and hardwoods have a minimum caliper diameter of 0.1 to 0.15 inches (2.5 to 4 mm) at the **root**

collar. This is the transitional area between the stem and the root. A good root system on a bare-root tree seedling is more important for success than a large stem. Survival, height and diameter growth of red oak seedlings were significantly greater on a test site in Iowa when bare-root seedlings had 10 or more first-order lateral roots growing from the taproot. This level of root development is not often achieved by nurseries growing millions of tree seedlings.

Bare-root seedlings are grown in nursery beds from one to several years. They are removed (called **“lifting”**) from the beds while dormant and sold or transplanted to a different bed for further growth. Nursery stock is sold based on the age and number of times the seedling has been transplanted. For example, seedlings grown in a bed for one season and sold are 1-0 stock. Seedlings grown two years with one lift and transplanted to a bed for the second season growing are 2-1 stock. The first number refers to seedling age, while the second refers to the number of times lifted and transplanted. Lifting cuts the deep roots of tap-rooted species, which stimulates lateral root growth. Improper lifting can result in shock to the seedling, leading to delayed growth or even death following planting.

Container-grown tree seedlings are becoming increasingly popular with many tree planters because they do not suffer from transplanting shock caused by the loss of or damage to the roots. The root system is transplanted intact at the time of out-planting, greatly improving establishment success. It is important to minimize transplanting shock of sensitive, large-rooted plants like oaks, walnuts and hickories encouraging the growing use of container-grown seedlings. While the cost of container-grown plants may be three to five times that of bare-root stock, higher survival rates on harsh mine sites can make the cost of container-grown seedlings very competitive.

Handling of Planting Stock

Correct handling of planting stock is crucial to establishment success. Prior to purchasing planting stock, the tree planter should inspect the nursery to ensure the material is handled correctly. Seedlings should be free of defects, correctly sized, graded, properly stored, packaged and shipped. Do not use nurseries that cannot meet these high standards. Some plant materials that do not meet quality standards may still be shipped. A good nursery will accept the return of defective material and replace it or credit it for a future purchase.

Once the stock is delivered, it should be protected from drying winds, freezing or hot temperatures and direct sunlight. Do not allow the roots to dry as this will greatly increase mortality rates. Stock can be covered in the field by straw, tarps or reflective heat blankets. The best protection is in a cool, dry barn, garage or other structure. Stock should be planted quickly following its shipment from the nursery. Bare-root stock should be inspected for defects once the bundles are opened. Roots should be protected from drying with moist, shredded papers, peat moss or other water-absorbent materials. Water-absorbent gels can be used to keep the roots moist while planting.

Bare-root seedlings can be stored for several weeks in the field by **“healing in.”** This technique allows the tree planter to extend planting time and affords better protection to the seedling in dry weather. Seedlings are removed from their shipping packaging and placed in the soil as if planted, making sure all roots are covered. Straw, hay or mulch is laid around the seedlings to hold in moisture and protect the tops. Keep the soil moist and protected from hard freezes. Do not allow the seedlings to sprout. Healing in is only a temporary field measure to protect seedlings that cannot be kept moist and stored in a cool, dark place.

One issue that always arises is that of pruning. Most experienced tree planters agree that the root-to-shoot ratio should be maintained around 1:1. Conifers should never have their topmost

shoot, or **leader**, pruned. Most hardwood species can be root-pruned to facilitate planting. Never prune more than 1/3 the total root area. Root pruning of hardwoods may require shoot pruning to maintain the 1:1 ratio. A shoot should be pruned slightly above a lateral bud to allow it to develop into a terminal shoot. Black walnut, pecan, white oak and other tap-rooted species can be extremely sensitive to root pruning. It may be best to use a shovel or tile spade to dig a hole deep enough to plant the entire tap root. Root pruning these species may lead to high mortality.

Planting Techniques

Correct planting techniques are simple but often overlooked. The chief goal of the tree planter is to plant the seedling with the least disturbance or damage to the seedling as possible. Trans-planting shock and improper planting techniques are important of high-quality seedling mortality. Container-grown seedlings can minimize these sorts of losses.

Seedlings should be planted with shoots near vertical, in a hole that is large enough to accept the roots easily without bending or twisting, and with the soil tamped gently around the roots without excessive compaction. Bare-root seedlings must be planted with the root collar at or slightly below the soil line. To minimize the potential of frost-heaving, bare-root seedlings must be planted after the last heavy spring frost date. In Missouri, they should be planted on mine sites between March 1 and April 10. The earlier plantings usually do better than late ones. Do not allow bare-root seedlings to sprout. Keep them chilled and out of the sun. Mortality rates soar for bare-root seedlings once the buds break.

Planters can use dibble bars, hoedads, mattocks, shovels or tile spades to plant trees. The method is not important if the roots are completely covered. The best planting method is to dig a hole with a shovel or spade but it takes more time than with other tools. If the mine soil is rocky, planting with a post-hole augur and tractor can be very effective. If the soil is wet, the rotary augur at high speeds can smear the sides of the hole and limit root penetration.

Mechanical planting is a cheap alternative to hand planting. Mechanical tree planters are pulled by a 60 horsepower (minimum) tractor. It cuts a slit in the soil into which the seedling is dropped into by an operator riding on the planter. Two or more press wheels follow behind and pinch the soil against the planted seedling. Both methods require correct handling and planting procedures for success. Mechanical planting is only as good as the efforts of the planting contractor and his or her equipment. Select a proven type of mechanical planter and an effective operator. Consult with state and federal foresters about the types of machines available and the operator's credentials in a region before issuing a contract. As with hand planting, find contractors who do good work.

Rugged terrain and rocky soils limit the use of mechanical planters. Wet soil conditions are not conducive to effective planting. Mechanical planters increase compaction on wet soils. Mechanical planting is quicker than hand planting. This can be important when there are many acres to plant and the planting window is short.

If you hire tree-planting work, inspect the trees and the work during and after the planting. Make sure all the trees were planted. Many landowners have purchased expensive planting stock only to find that the planter has thrown some of the seedlings into the bushes, or switched to lesser-quality stock or even to different species if no one was there to prevent the switch. All trees should be handled and planted correctly. All trash should be picked up by the planter. Place a guarantee clause in the tree-planting contract to compel the contractor to perform correctly. Require performance bonds and reference checks. Good tree planters prefer clear stringent contract conditions requiring good planting techniques.

Control of Competing Vegetation

Effective control of competing vegetation often is overlooked prior to tree planting. Dense ground cover is desirable to prevent erosion and sedimentation on a reclamation site. However, it limits successful tree establishment and may increase rodent populations, which can destroy tree seedlings. It also may enhance browsing by deer and rabbits. Water is usually the most limiting factor in tree-seedling establishment on mine lands.

The extensive root systems of herbaceous plants out-compete young seedling roots for water and nutrients as the seedlings overcome transplant shock and summer droughts. Competing herbaceous plants can overtop tree seedlings, reducing photosynthesis, and cause shoot die-back. Competition can lead to high seedling mortality. Competing vegetation should be controlled for at least two growing seasons to promote seedling establishment. Some researchers suggest that four or five years of control is necessary for high growth rates.

Aggressive allelopathic species, such as tall fescue (*Festuca arundinacea*) should not be used as a cover species in areas to be planted in trees. Less competitive or aggressive species such as redtop (*Agrostis alba*), timothy (*Phleum pratense*) or perennial ryegrass (*Lolium perenne*) should be planted at rates of two to four pounds of pure live seed per acre. A low-growing legume such as white clover (*Trifolium repens*) or common lespedeza (*Lespedeza striata*) can be planted at similar low seeding rates to add nitrogen. Adapt cover crop selections to local conditions.

Competing vegetation can be removed by “scalping.” This can be done mechanically by disking, roto-tilling, drag bucket, or manually by using hoes, mattocks or shovels. Vegetation is scalped, leaving bare soil to receive the planted seedlings. This process can be expensive, time-consuming and labor intensive, but very effective in improving establishment success. Applying herbicides in strips or spots around the tree is less expensive than physical scalping and very effective for vegetation control. Environmental and human health issues must be considered when using herbicides. All chemical applications must be performed according to label directions. Never apply chemicals in standing water or to the trees directly.

The land manager should not scalp vegetation in such a fashion as to promote erosion. Always disc or apply herbicides along the contour, leaving swales, ditches and channels undisturbed and well-vegetated. Clip the tops of tall annuals such as ragweed that may overtop seedlings in the first season with a sickle bar or a hydraulic arm mower set high enough to miss the seedling. The mowed material can be raked or thrown at the base of the seedling as an organic mulch.

Tree shelters, ground cover control blankets and mulches also can be very effective, but are costly and labor intensive. Tree shelters are particularly effective in protecting seedlings from animal browsing and from spot herbicide applications. Manufacturers claim the growth is accelerated in the spring, and water evaporation is minimized by the shelters. Researchers found that tree shelters with or without deep-ripping, greatly improved survival of white oak seedlings on a reclaimed dragline coal mine in Illinois. Birds often use the shelters for perches, sometimes breaking young shoots. Paper wasps and mud daubers build nests inside the tubes, posing a hazard to inspectors.

Soil Conditioning and Preparation

Proper soil conditioning and soil preparation are the foundations of successful tree establishment. Certain soil conditions must be present before trees can be successfully established. Mine spoils tend to be low in organic matter, nitrogen and phosphorus. Water infiltration is slow, and water-holding capacity is low in graded mine spoils due to compaction. Compacted mine

soil accentuates the effects of soil acidity on plants and decreases water availability. Some mine spoils contain acid-forming or toxicity-forming materials that impede seedling establishment.

Reclamation is a soil-building process. In natural systems, drastically disturbed lands undergo a succession of living organisms that may take decades or even centuries for successful colonization to occur. The foundation of successful reclamation is the development of a sustainable, functioning soil ecosystem. Soil organisms play an essential role in nutrient cycling and soil productivity. Reclaimed mine sites initially have low levels of soil organisms. Without organisms, plants perform poorly on most mine sites. Slowly, beneficial soil organisms colonize reclaimed areas, allowing plants to become established.

Low soil pH can greatly affect seedling establishment. Acid-forming materials present in many mine spoils can lower soil pH far below what is acceptable for most tree species. As the pH drops, metals such as aluminum, manganese and iron increase in the soil solution. Aluminum is especially toxic to plant root growth. Aluminum toxicity is a major problem in most acid soils. As a general rule, do not plant hardwood trees on mine soils with a surface pH of 5.0 or less without first amending the soil. Amend acidic mine spoils with neutralizing materials such as agricultural lime, or spread two to four tons of decomposed organic matter per acre to buffer the acidity and raise the pH. These amendments should be incorporated by methods that will not cause erosion. If the site is ungraded, plant seedlings in less acidic locations. These include protected sites such as valleys and depressions, which retain moisture and organic matter. Trees will spread from these areas into barren areas with time. Natural succession will finish the reforestation job in later years. Plant acid-tolerant native species and rhizomatous plants to promote natural succession and to improve the mine soil. Islands of vegetation in mine soils indicate natural invasion patterns, providing clues to the location of these better planting sites.

Mine spoil fertility can be improved by growing nitrogen-fixing cover crops such as legumes. Plants create soil organic matter that promotes nutrient cycling and soil microbial activity. Virtually all plant-available nitrogen and phosphorus in soils are derived from the decomposition of organic matter by microbes. Organic matter increases water-holding capacity, increases cation exchange capacity, buffers soil pH, lowers soil bulk density and promotes the development of a diverse, soil microbial population. These factors greatly improve the success of seedling establishment. Green manure cover crops can be disced into graded mine spoils to improve soil fertility and organic matter levels. Organic matter can improve soil pH and buffer the exchangeable acidity, improving revegetation and seeding establishment success.

Low mine soil fertility also can be addressed by organic matter applications and chemical fertilization. While cheap and effective, chemical fertilizers can pose environmental hazards if improperly used and may impede the development of native plants adapted to soils with low fertility levels. The land manager must consider the long-term goals of reclamation to determine the proper course of action. Mine soils low in nitrogen or phosphorus may require additions of chemical fertilizer or applications of nutrient-rich organic matter like manure to correct these deficiencies. Nitrogen-producing legumes also can play a major role in improving fertility. Virtually all nitrogen and phosphorus in the soil comes from the decay of soil organic matter as a result of soil microbial organisms. Chemical fertilizers can play a role, but long-term soil fertility on mine soils largely depends upon adequate soil organic matter and microbes to convert it into plant nutrients.

Water is the most limiting factor in tree or shrub establishment. Excessive compaction of clay-dominated mine spoils caused by heavy earthmoving equipment decreases mine soil water-holding capacity. Tree roots have difficulty penetrating compacted mine soils. The effects of drought are accentuated in compacted mine soils, often resulting in transplanted seedlings dying

because their root systems are not extensive or deep enough to obtain water in the summer. Compaction also impedes the infiltration of water into the mine soil. In wet periods, this can result in waterlogged or anaerobic conditions that can kill seedlings or severely damage their root systems. Ironically, wet mine soils can become very dry in summer because water and plant roots cannot penetrate deeply into the compacted soil. Plants must be able to survive both extremes. The result is that compacted soils can be very difficult to revegetate.

Deep ripping by ripper bars, subsoilers, V-shank rippers or some plows pulled by bulldozers is often effective in breaking up compaction, while increasing water infiltration and penetration of tree roots. Ripping down 24 to 48 inches greatly improves seedling establishment rates. A second pass, angled on a 60-degree bias rather than perpendicular to the first, seems to be most effective in breaking up compacted soil. In 1997, ripping costs ranged from \$100 to \$200 per acre, to a depth of 24 to 36 inches on two-foot centers. In a study on a Missouri mine site, tree-planting expenses in 1995 totaled \$200 to \$300 per acre. Ripping increased first season bare-root survival rates from 30%-40% to 60%-80% for an investment of \$100 to \$200 per acre, resulting in a total tree-planting cost ranging from \$300 to 500 per acre. The extra expense may be offset by not replanting compacted areas. Ripping may be the critical factor in stand survival in a drought year. Ripping increases surface roughness, which promotes water retention in small depressions. Ripping slows near-surface wind velocities, reduces erosion and slows evapotranspiration, the loss of water vapor from plant leaves. Ripping may increase rodent predation of seedlings by providing habitat and easier access to roots. While this may be locally devastating, heavy rodent predation tends to be cyclical, tied to vole and other rodent population cycles.

Weather

Weather can be the most crucial factor in tree-planting success. As mentioned previously, water is usually the most limiting factor in tree-seedling establishment. All the best soil preparation, high-quality planting stock and proper planting methods can go for naught if it does not rain. Plant trees and shrubs just prior to the period of maximum season precipitation. Droughts like those of 1980 and 1988 or even a pronounced spring drought during the first season can cause excessive seedling mortality. The tree planter should believe that the weather will be favorable and that the best-laid plans and the expense will not be in vain. However, when the weather is not favorable, the tree planter must accept failure, adapt to new conditions and revise plans, but never give up.

Conclusion

Successful tree seedling establishment largely depends on the seven factors listed in the introduction of this paper. Water is the chief limiting factor in seedling establishment. Compaction is the chief culprit in limiting tree-root development, drought tolerance, water infiltration rates and water-holding capacity of mine soils. Competition by herbaceous vegetation is a significant cause of tree seedling mortality. Soil chemistry plays a major role in establishment success since many weathering byproducts of mine soils are salts that absorb water and disperse clay particles. Acid-forming materials decrease soil pH which limits nutrient availability, soil microbial populations and solubilize metals in mine soils. Aluminum is especially a problem because it is extremely toxic to plant roots. Low organic matter levels in mine soils result in low nutrient levels, particularly nitrogen and phosphorus, poor nutrient cycling and low soil microbial populations. These conditions can be overcome by adequate analysis of soil conditions and soil preparation. Soil preparation includes liming, ripping, scalping, fertilizing and the use of green manure crops.

Purchase good planting stock of locally adapted native species, especially if the mine soils are acidic. The stock must be correctly handled and planted. Once all this is done, establishment is

largely up to nature. If weather conditions are favorable, the stand should be successfully established in the critical first season. However, the tree planter must be patient and understand that tree-planting success takes time. Trees are slow-growing, long-lived plants. A forest will not be created in a day. Finally, get out and observe what works on the mine lands and adapt to local conditions.

Clark Ashby of the Southern Illinois University at Carbondale found that natural succession processes on drastically disturbed lands mimic classic old-field succession. Often, desirable oak and nut trees are not growing near mine lands in the Midwest and therefore, cannot colonize them. Tree planting can improve wildlife habitat by introducing desirable tree species to mine lands. Native species produce valuable timber and nut crops on mine lands. Forest management practices allow a mine site to develop a soil system that improves long-term site stability and productivity. Disturbance is minimal in comparison to more intensive land practices like haying or grazing. The long life span of trees encourages ecosystem stability. But perhaps more importantly, tree planters become actively involved in healing the land after mining. The pride of accomplishment only builds as the trees grow and the land begins to blend into the surrounding landscape. Tree planting is an act of faith in the future and a commitment to future generations.

For more information, refer to Technical Assistance Bulletin No. 7, ***Tree Species for Planting on Missouri Mine Lands***, or call DNR's Land Reclamation Program at 1-800-361-4827 or (573) 751-4041. Forest and wildlife management information can be obtained by calling the local Missouri Department of Conservation office.

A Summary of DOs and DON'Ts for Reclamation with Trees*

DO:

1. Rip or at least chisel-plow compacted sites before planting.
2. Avoid dense ground cover of highly competitive species.
3. Use herbicides as needed.
4. Make sure tree seedlings or seed is properly stored and planted.
5. Plant at the right time.
6. Keep tree roots moist at all times.
7. Use adapted woody species from similar climatic zones.
8. Choose species not palatable to deer if browsing is a problem.
9. Protect trees after planting.

DON'T:

1. Avoid stony soils.
2. Apply high rates of fertilizer.
3. Sow highly competitive types of ground cover.
4. Sow ground cover at high rates.
5. Plant unhealthy or damaged stock.
6. Plant seedlings that are too small or prune large stock excessively.

* Reprinted with permission, Ashby, W. Clark, and Willis G. Vogel. Tree Planting in the Midwest: A Handbook. Coal Research Center, Southern Illinois University, Carbondale Illinois, 1992.

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For more information call or write:

Missouri Department of Natural Resources

Land Reclamation Program

P.O. Box 176, Jefferson City, MO 65102-0176

1-800-361-4827 or (573) 751-4041 office

(573) 751-0534 fax

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